Towards Understanding the

# Origin of Cosmic-Ray Positrons

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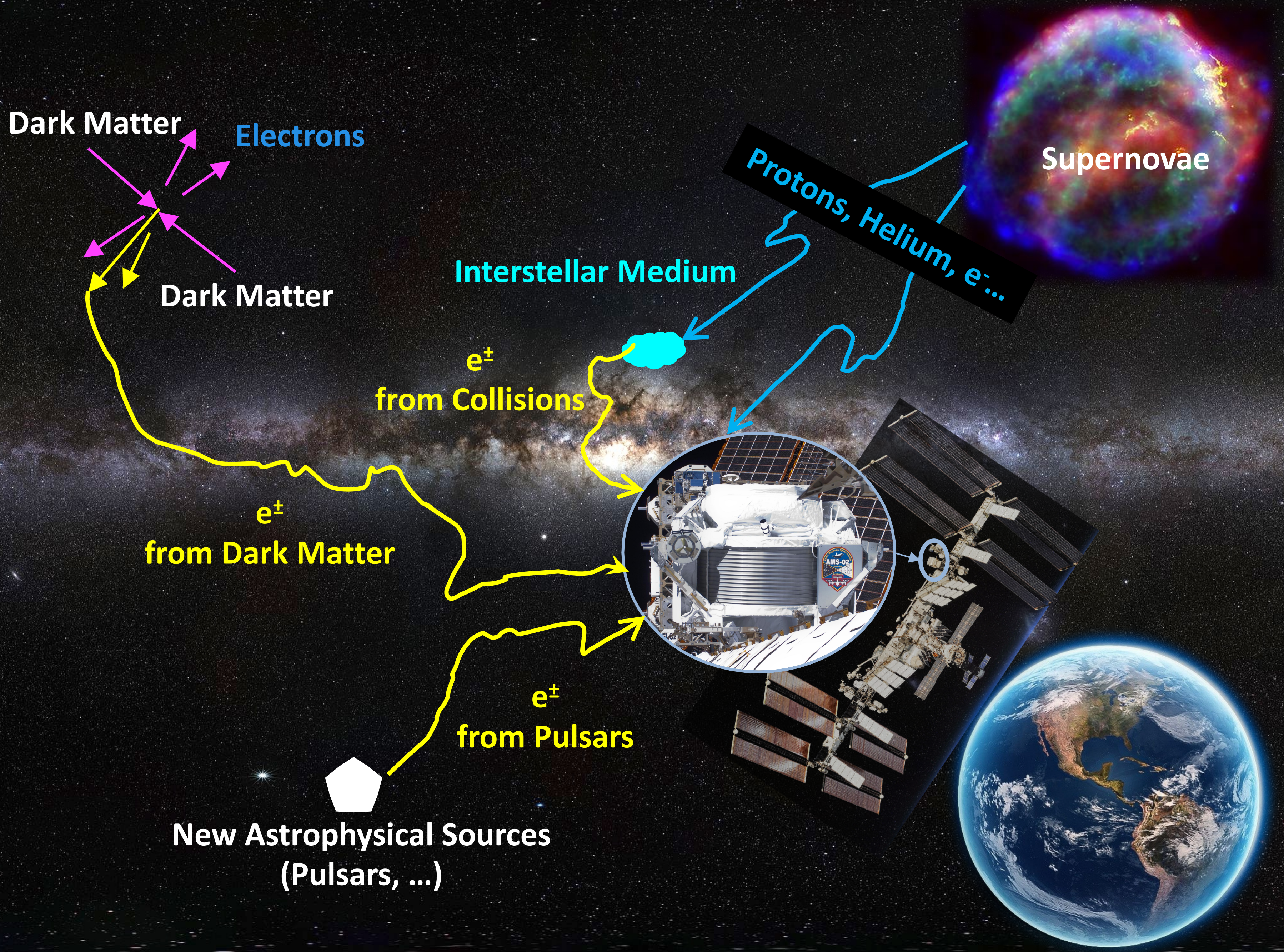
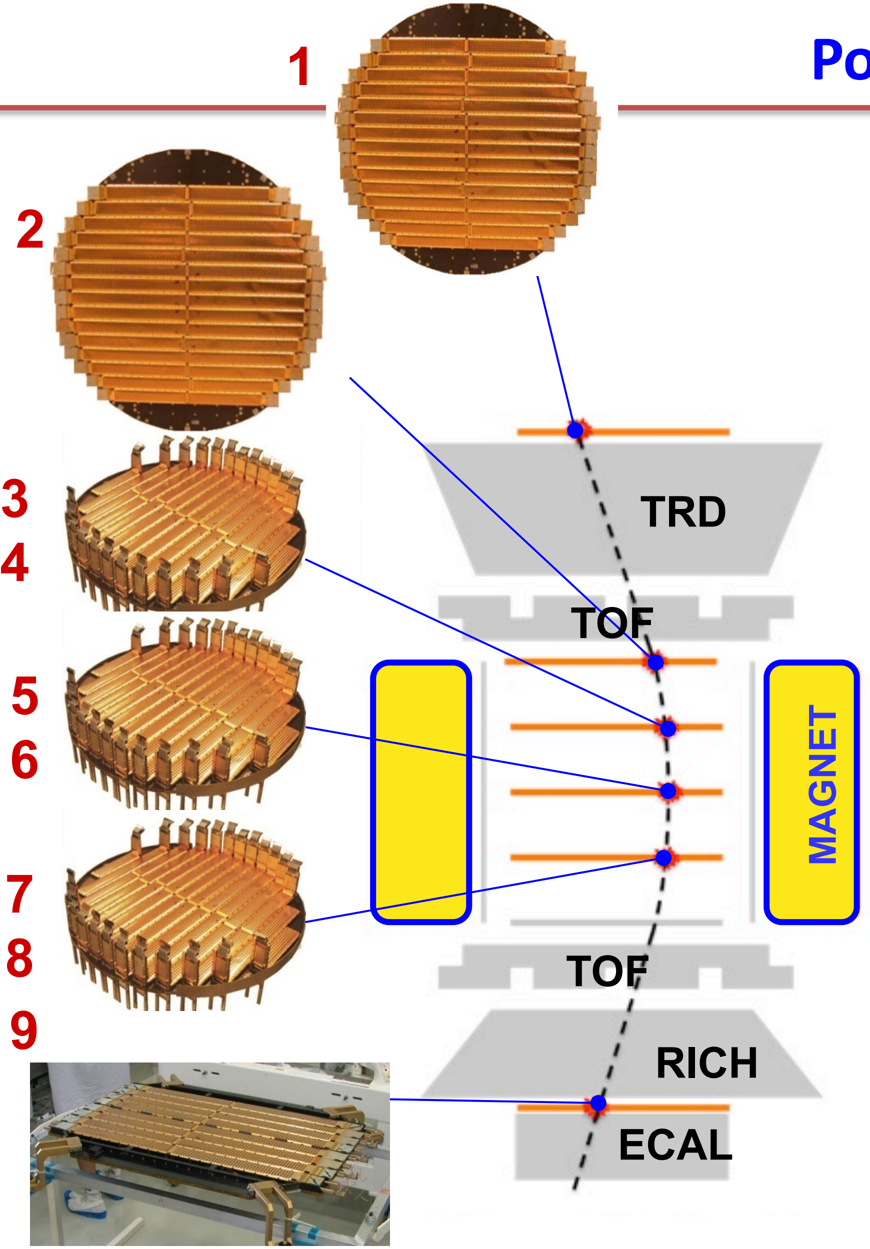
on behalf of the AMS Collaboration


37th ICRC, July 2021

# The Origins of Cosmic Positrons

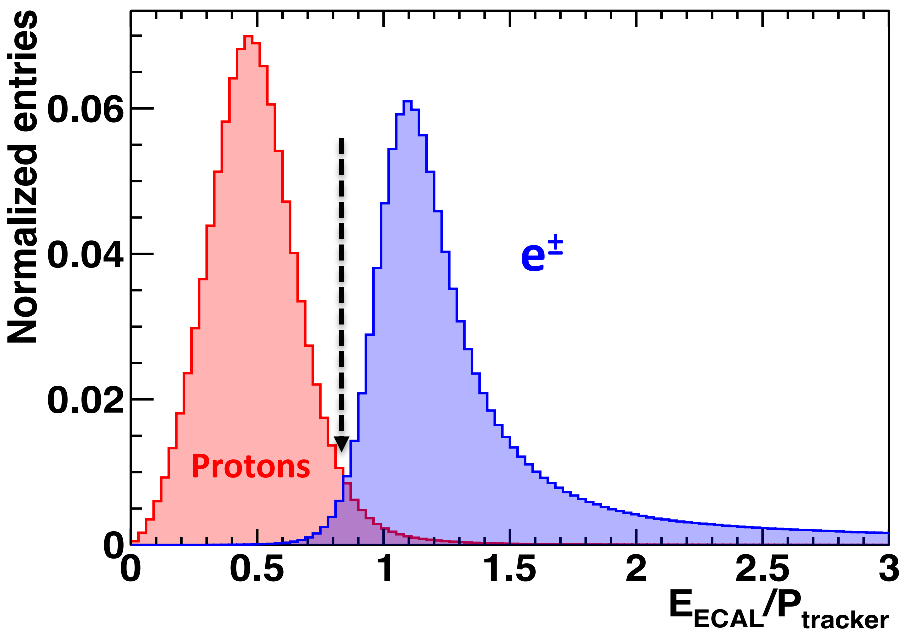


# Positron Measurement in AMS



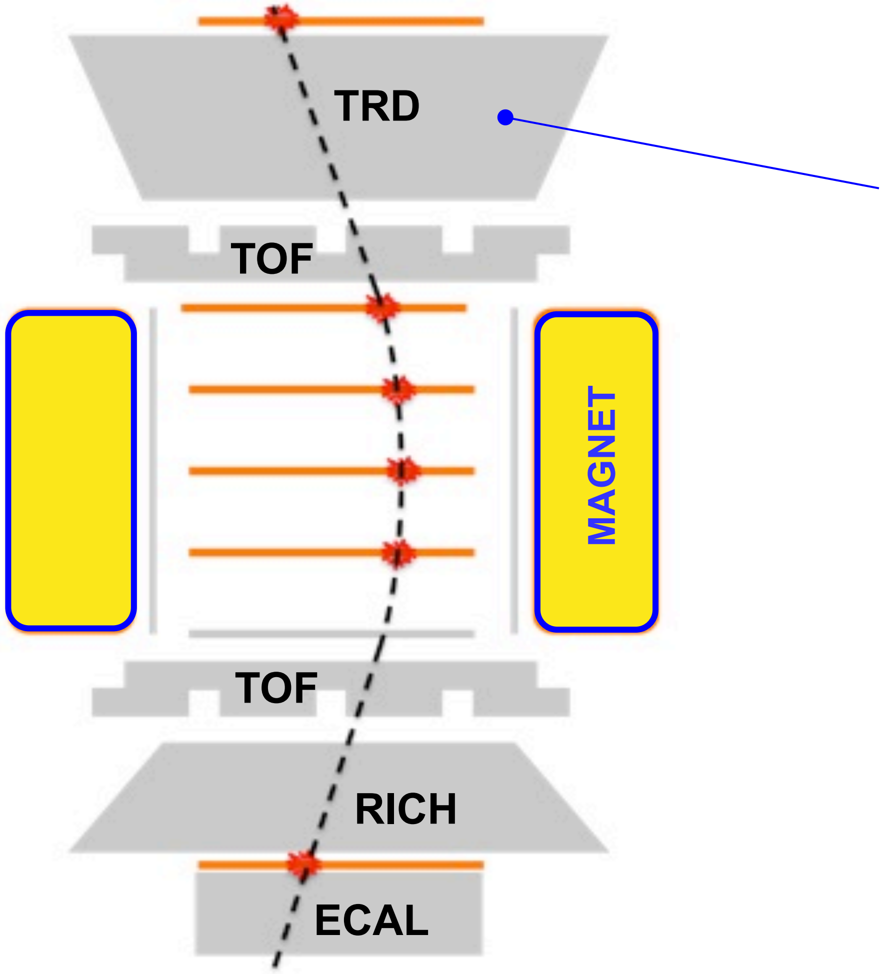

L1 to L9: 3m level arm;
single point resolution 10 μm;

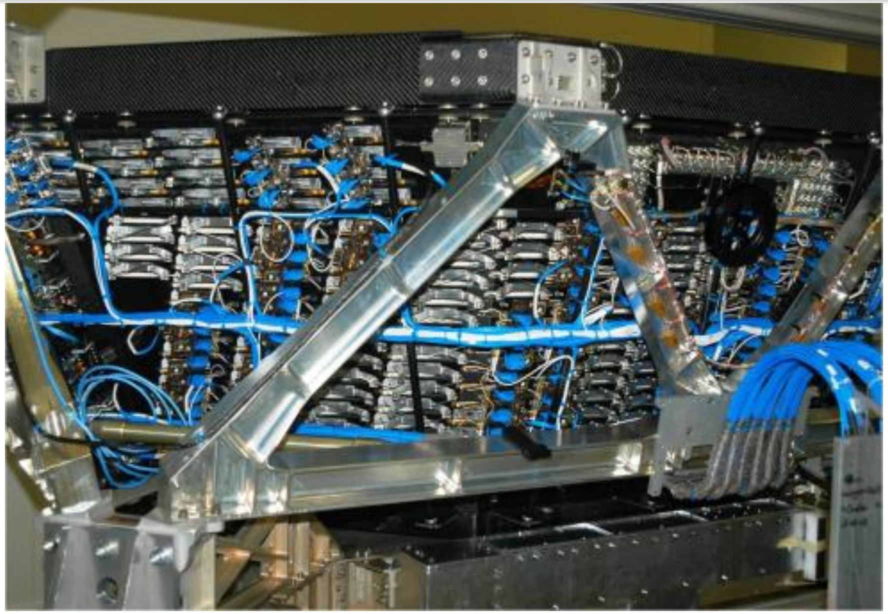
- Tracker and Magnet Measures the sign and magnitude of positrons and electrons to few TeV.
- Unique particle identification capability of AMS: Independent Momentum and Energy measurement



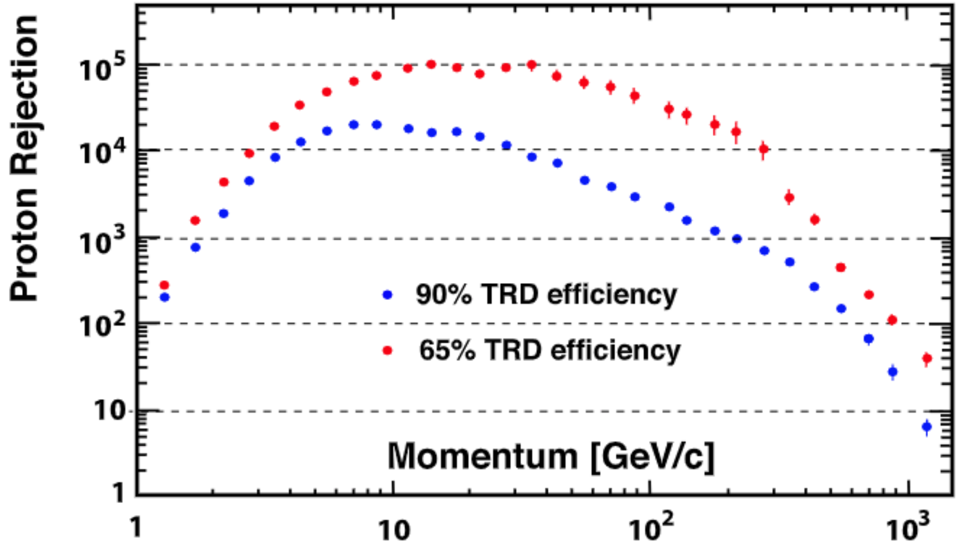

- Identify electron charge confusion:
  - Large angle scattering,
  - Interaction with detector materials.
  - Identified and measured from data using Charge confusion estimator $\Lambda_{CC}$

# Positron Measurement in AMS



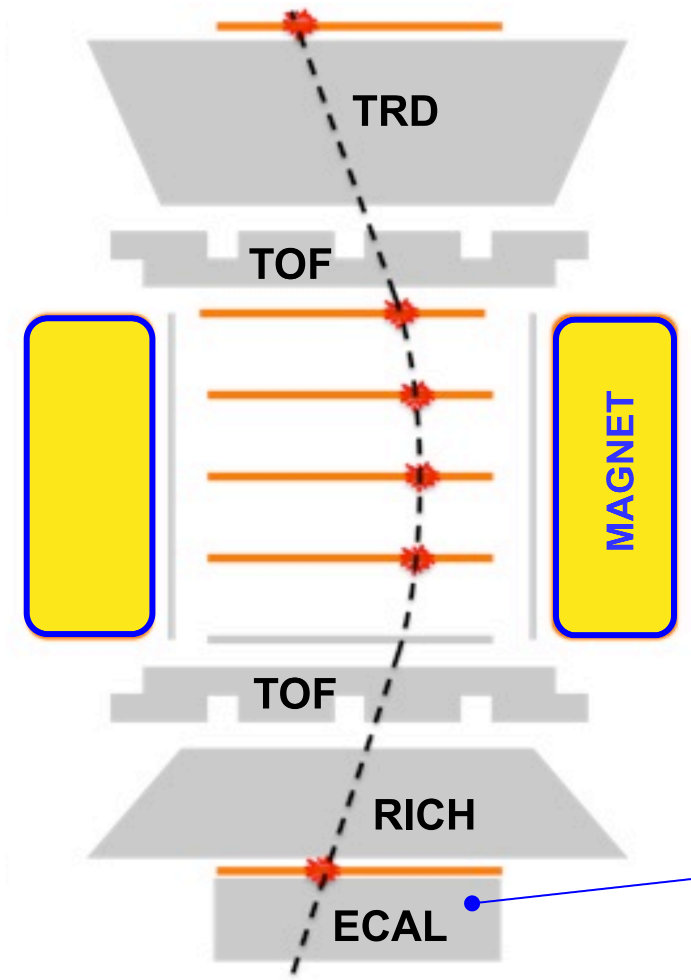



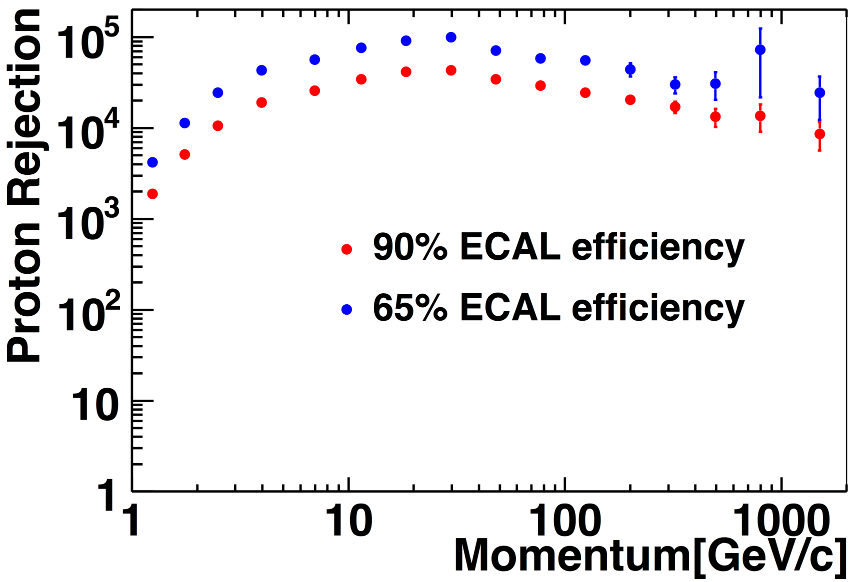
TRD proton separation at different $e^{\pm}$ efficiency




- TRD: Identify $e^{\pm}$ from protons using transition radiation. Combine 20 layers proportional tubes signal: $\Lambda_{\mathrm{TRD}}$ .

# Positron Measurement in AMS




- ECAL : 17 $X_0$ , TeV Precision 3D measurement of the energy and shower development of electrons and positrons.

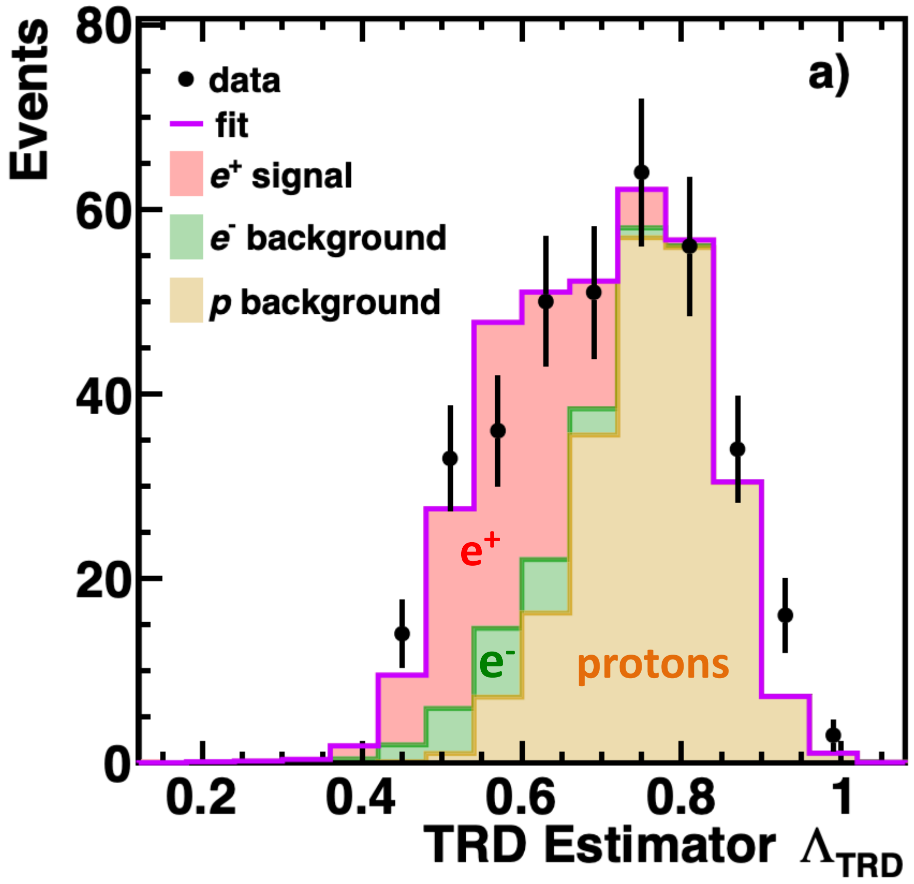
**TRD and ECAL are separated by the Magnet**

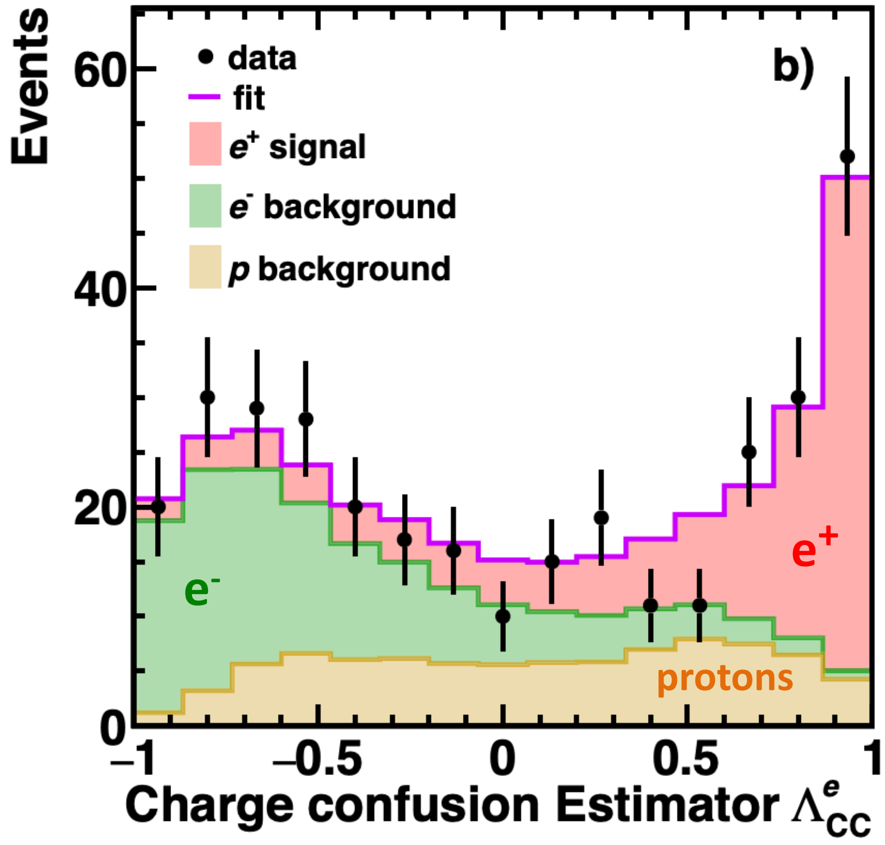
**They have independent particle identification: combined rejection > 1 in $10^6$**

# Positron Measurement in AMS

- After selection by ECAL, number of $e^+$ are obtained from a fit to data sample in $(\Lambda_{TRD} - \Lambda_{CC})$ plane
- Precision determination of Signal and Background from Data
    - Positron Signal are clearly identified in the signal region of $\Lambda_{TRD}$ and $\Lambda_{CC}$
    - Proton : identified by TRD estimator $\Lambda_{TRD}$
    - Electron charge confusion measured from data using Charge confusion estimator $\Lambda_{CC}$

Fit to Data, Positive Rigidity, 370 – 500 GeV



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Editors' Suggestion

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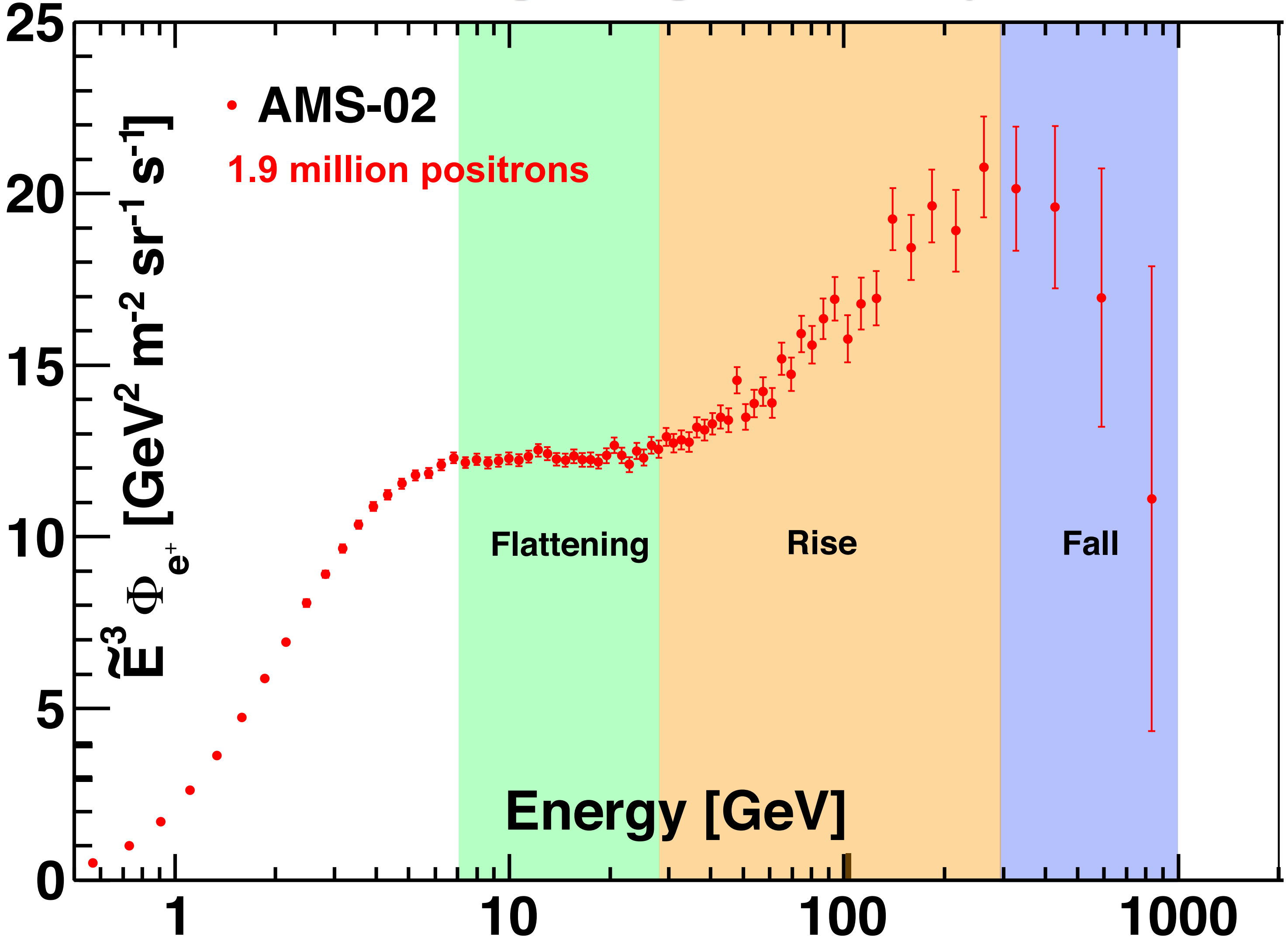
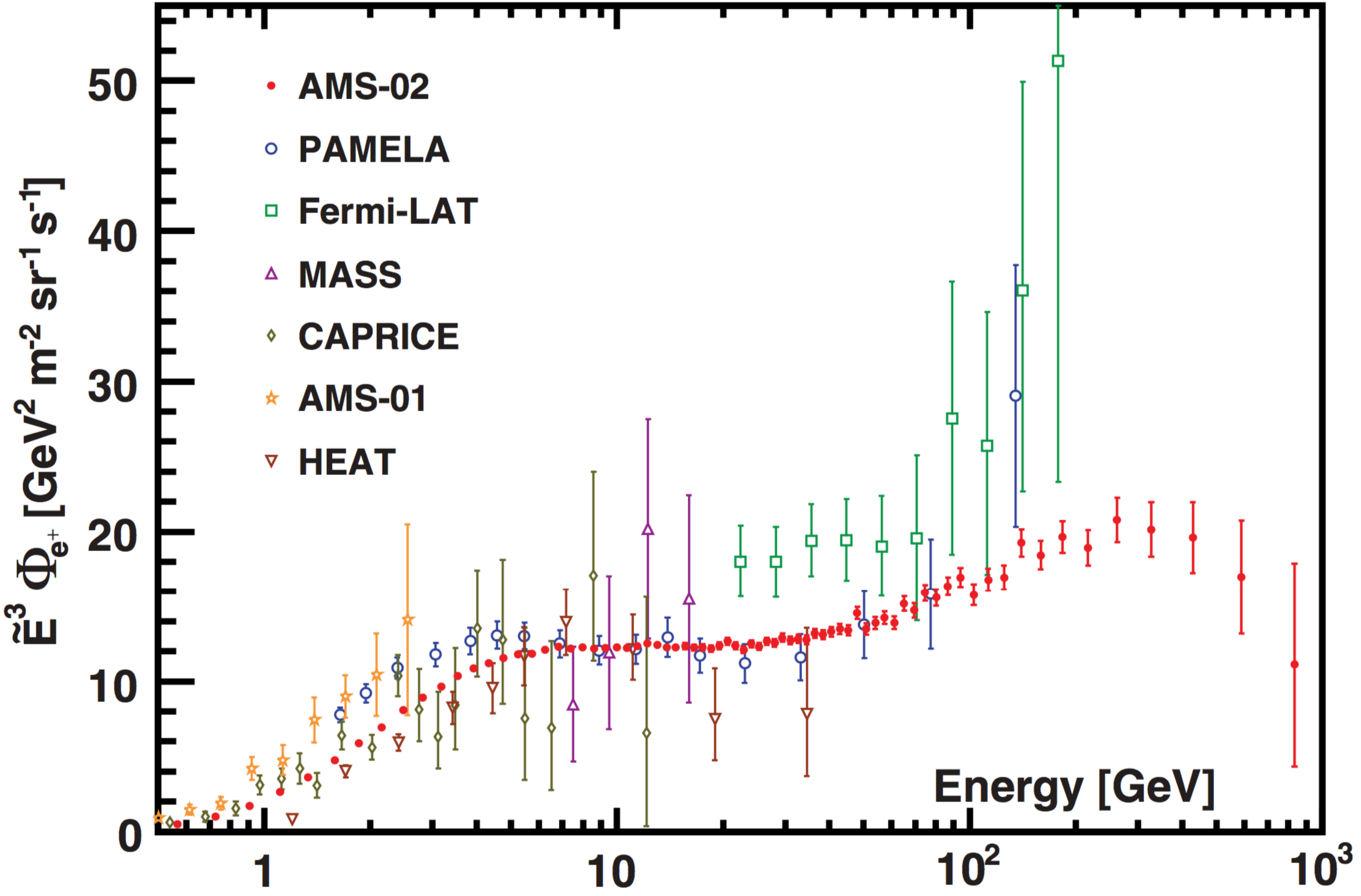
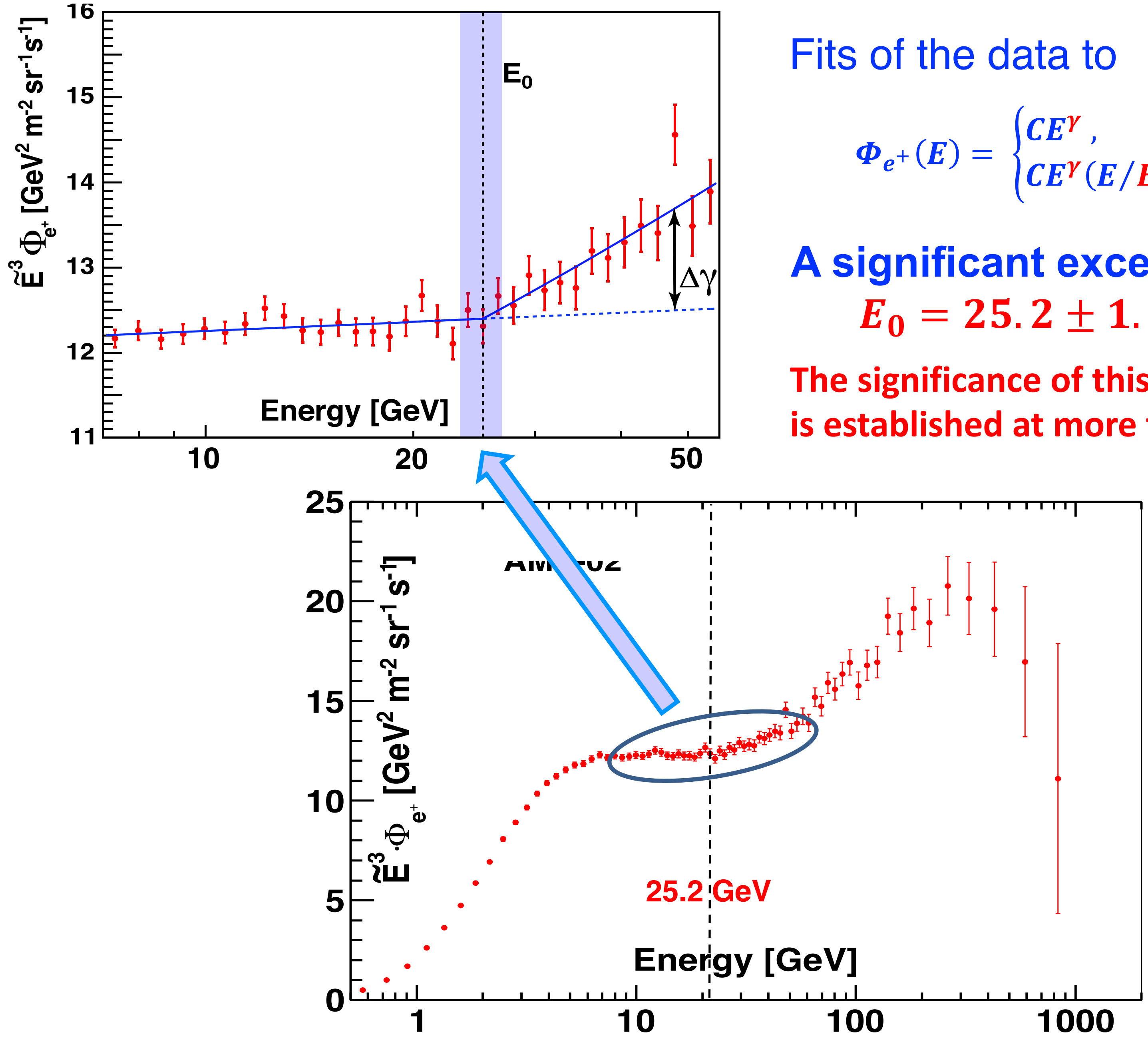



**Positron spectrum exhibits complex energy dependence**

# AMS Positron Measurements to uncharted Energy Range



# Distinctive properties of Positron Spectrum



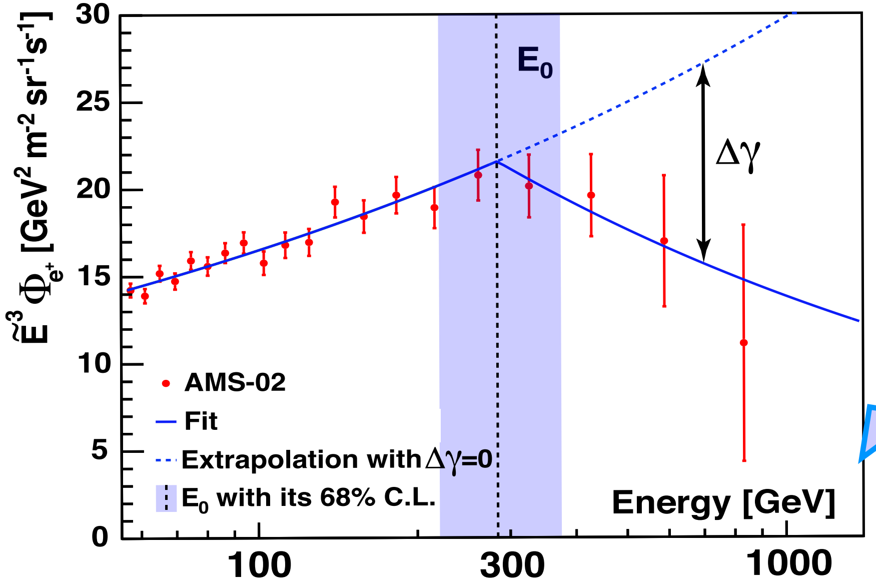

Fits of the data to

$$\Phi_{e^+}(E) = \begin{cases} CE^{\gamma}, & E \le E_0; \\ CE^{\gamma}(E/E_0)^{\Delta\gamma}, & E > E_0. \end{cases}$$

**A significant excess above**
**$E_0 = 25.2 \pm 1.8$ GeV**

**The significance of this change is established at more than 6σ**

# Distinctive properties of Positron Spectrum



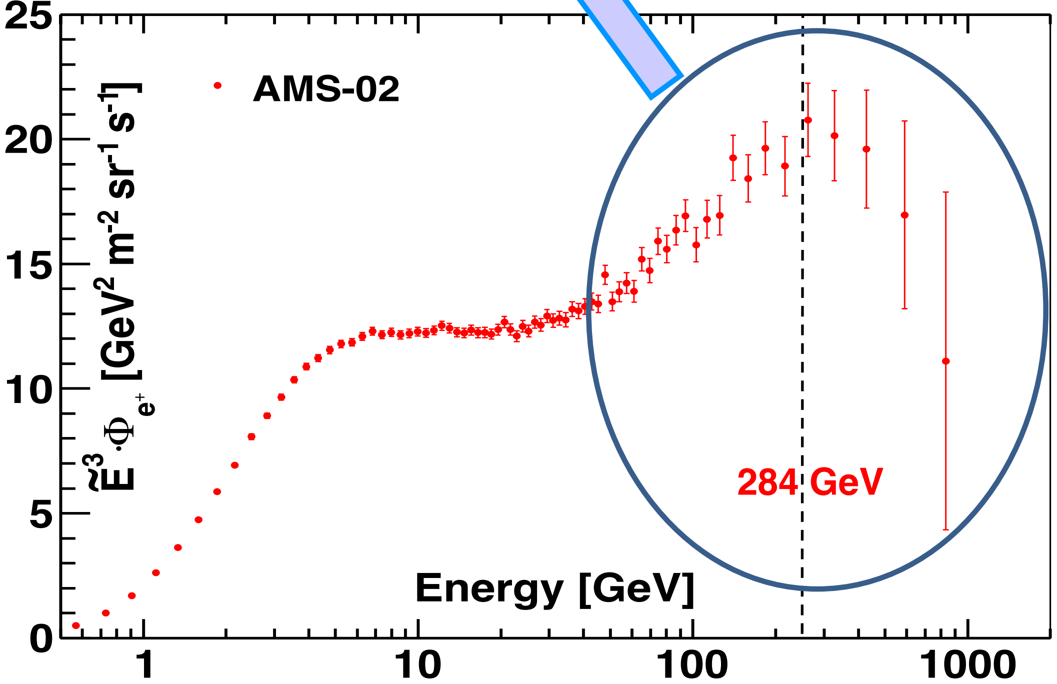

Fits of the data to

$$\Phi_{e^+}(E) = \begin{cases} CE^{\gamma}, & E \le E_0; \\ CE^{\gamma}(E/E_0)^{\Delta\gamma}, & E > E_0. \end{cases}$$

**A sharp drop-off at**

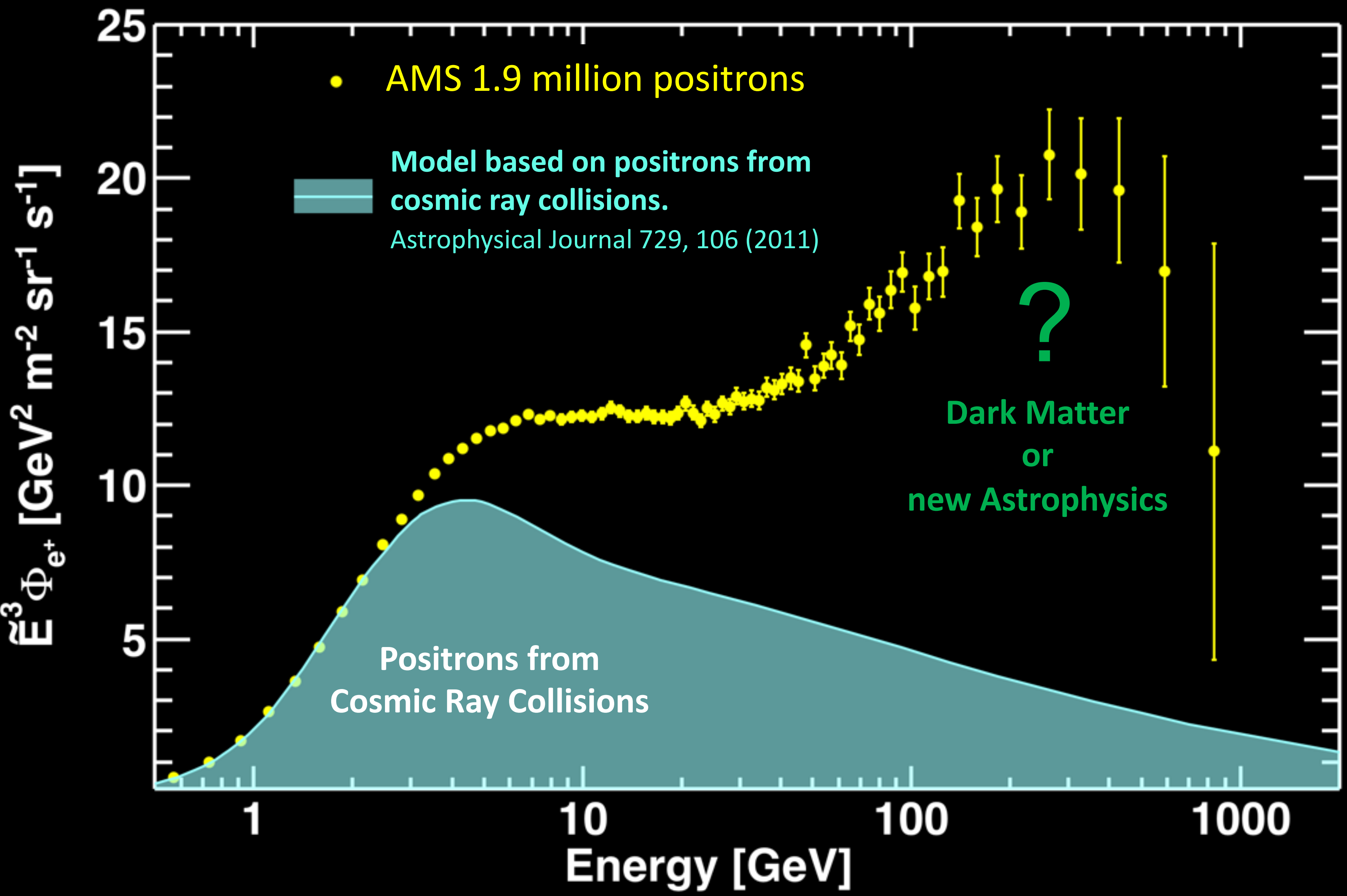
$E_0 = 284^{+91}_{-64}$ **GeV**

**The significance of this change is established at more than 3σ**

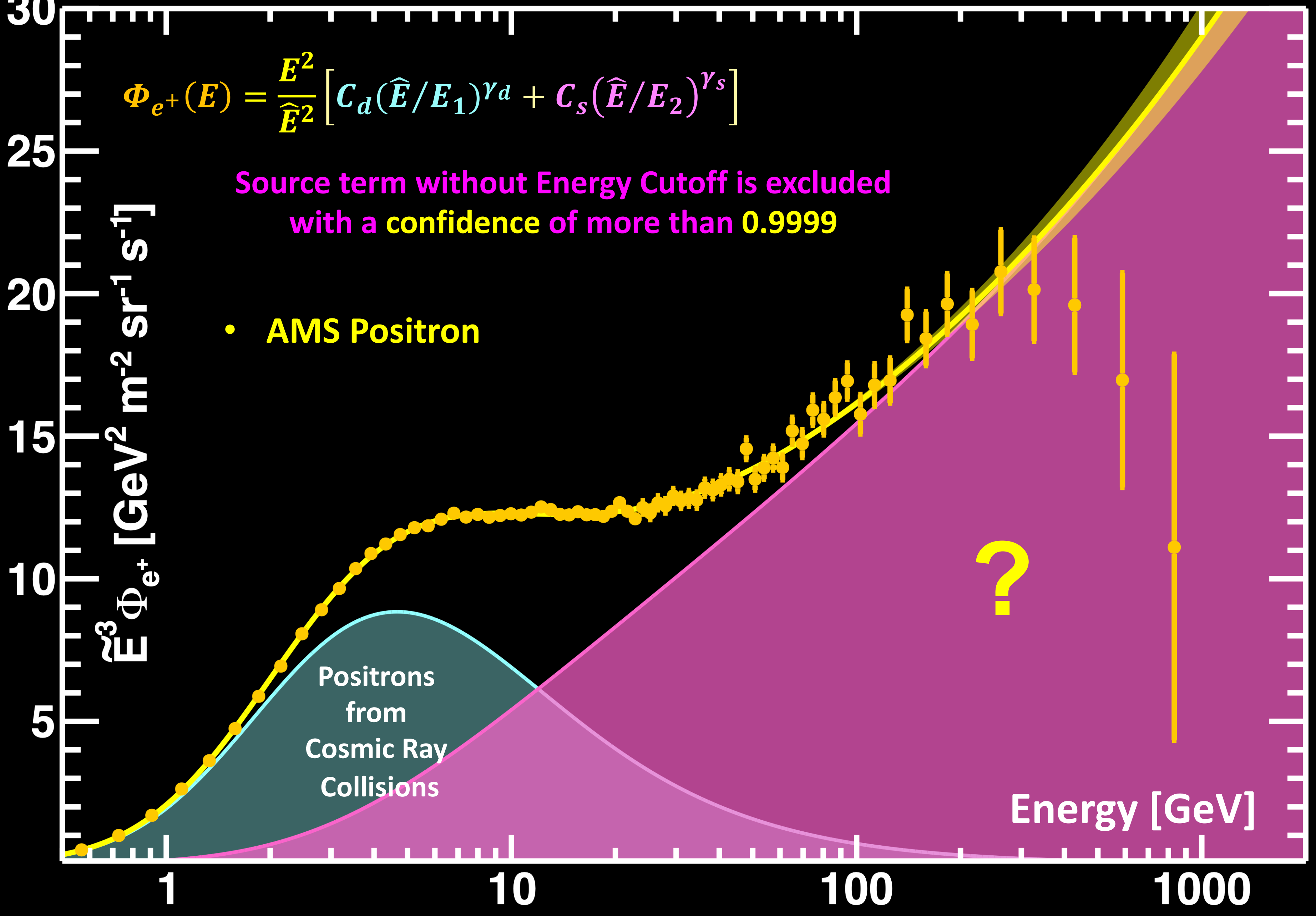


## The Origin of Cosmic Positrons

**These distinct behavior can not be explained by traditional cosmic ray models.**

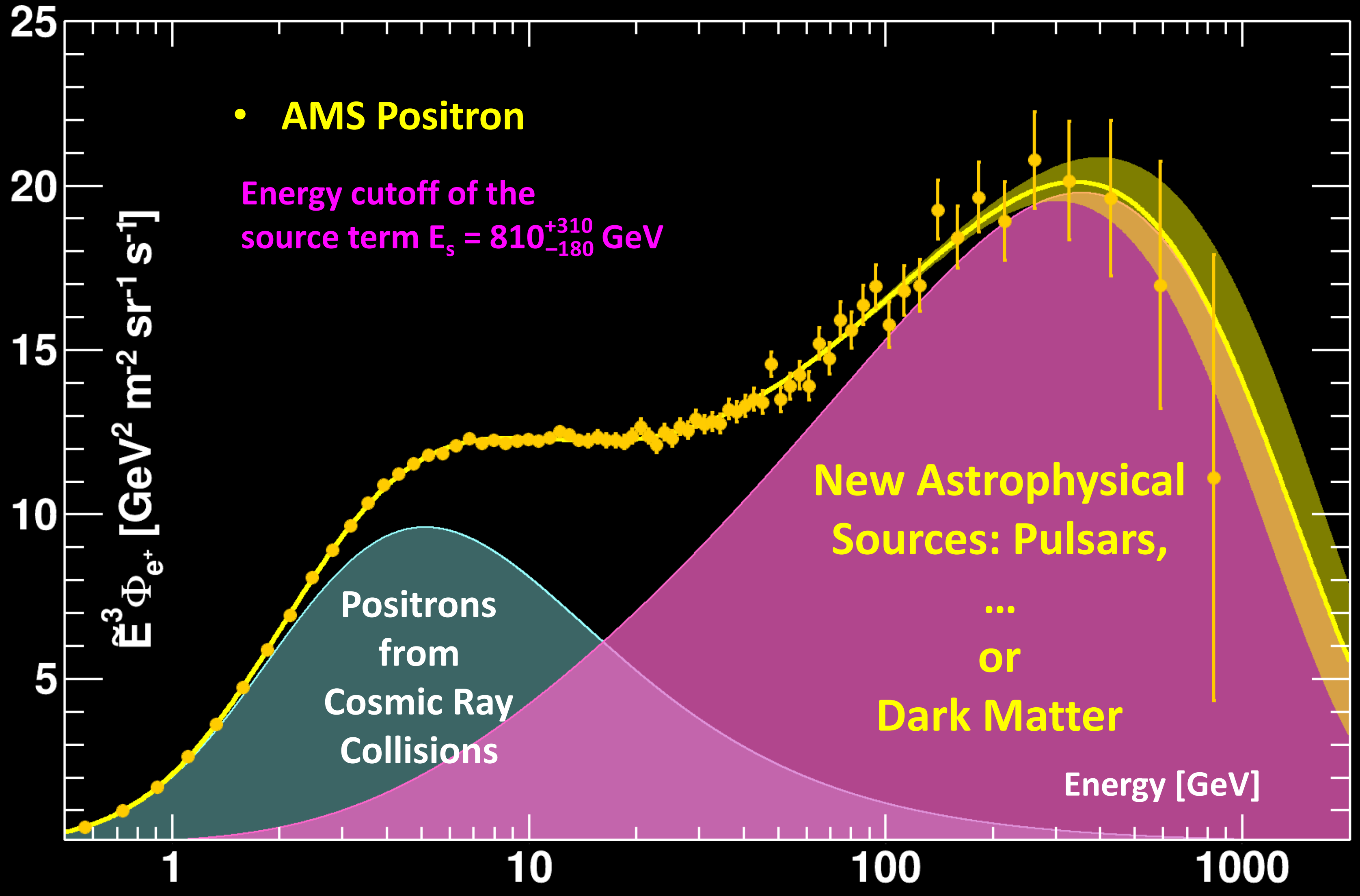


# Energy Cutoff of Positron Spectrum



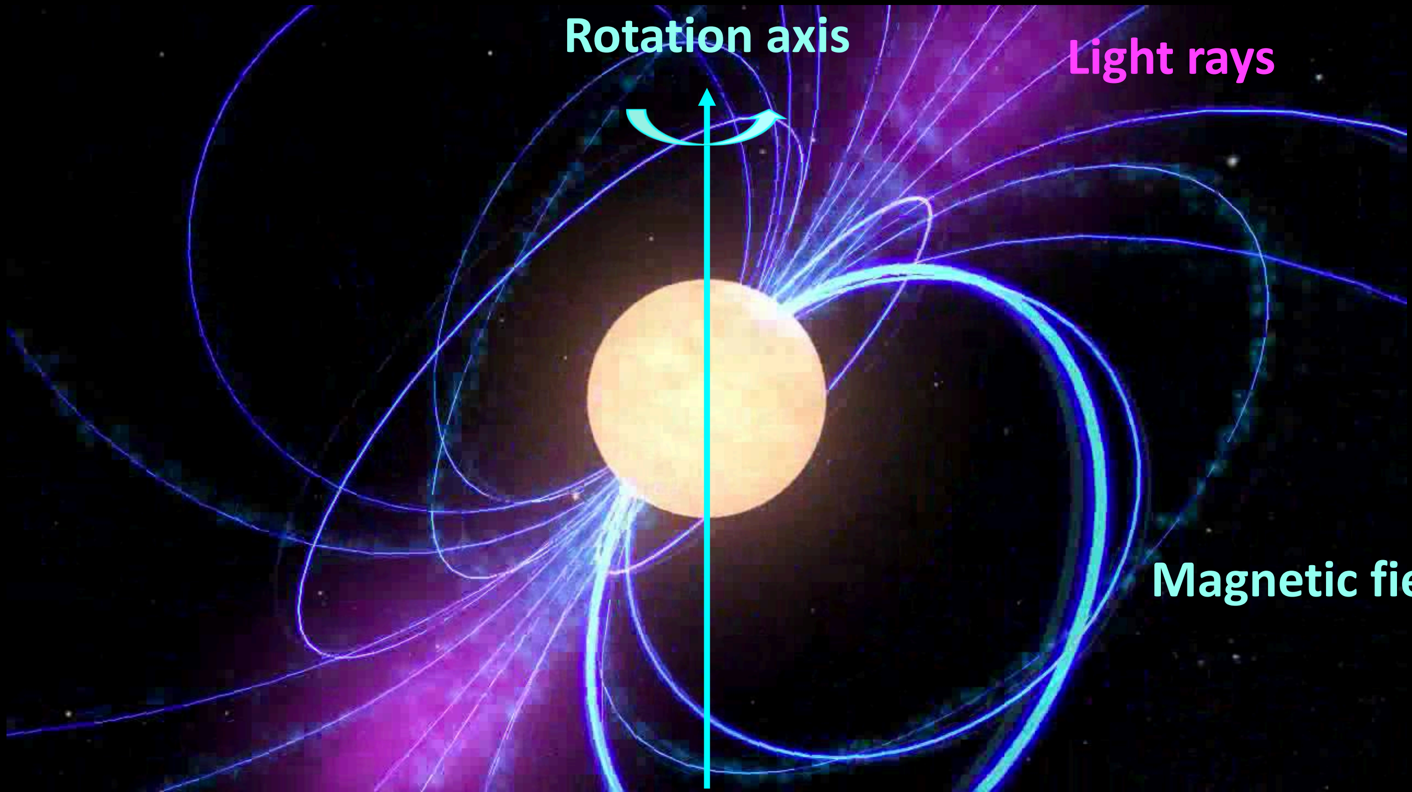
The positron flux is the sum of low-energy part from cosmic ray collisions plus a high-energy part from pulsars or dark matter.

$$\Phi_{e^+}(E) = \frac{E^2}{\hat{E}^2}\left[C_d(\hat{E}/E_1)^{\gamma_d} + C_s(\hat{E}/E_2)^{\gamma_s}\exp(-\hat{E}/E_s)\right]$$

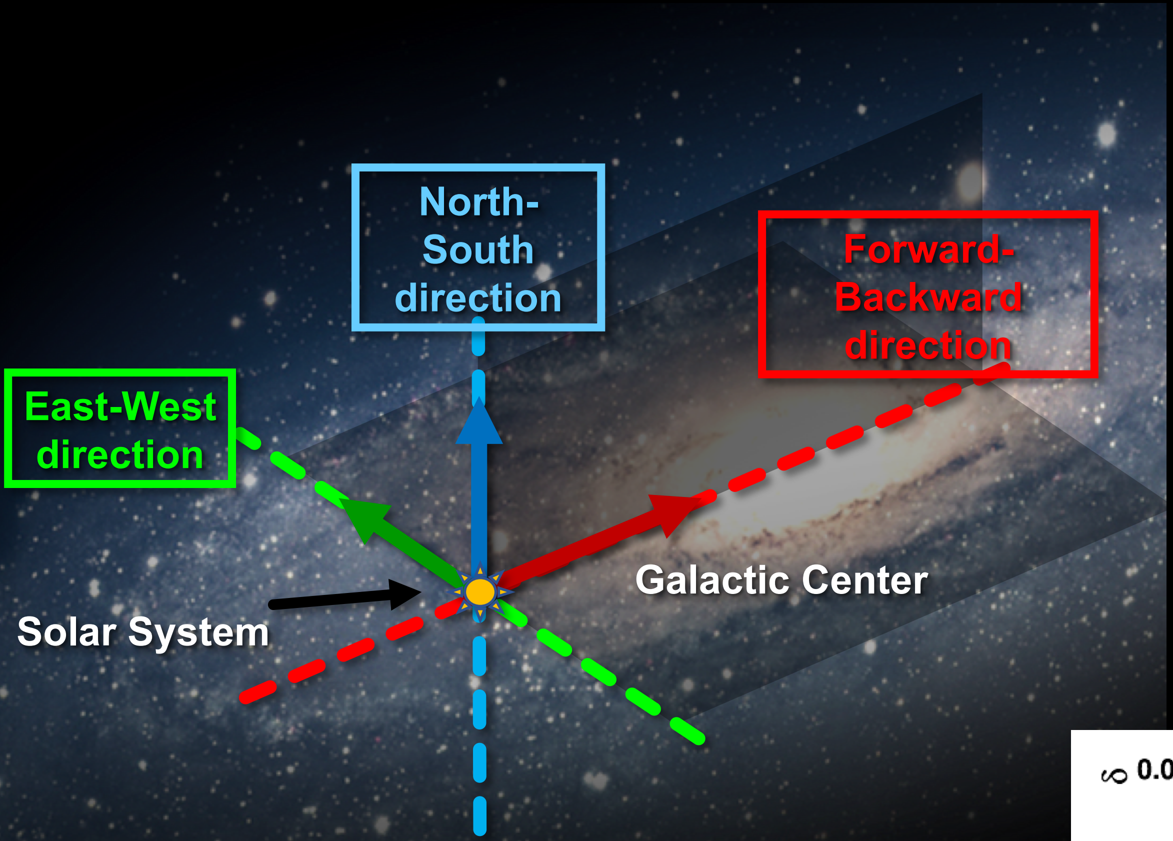


# New Astrophysical Source: Pulsars

- Pulsars produce and accelerate positrons to high energies
- High energy positrons from pulsar imprints directional anisotropy
- Pulsars do not produce antiprotons.



# Analysis of the Positron Anisotropy

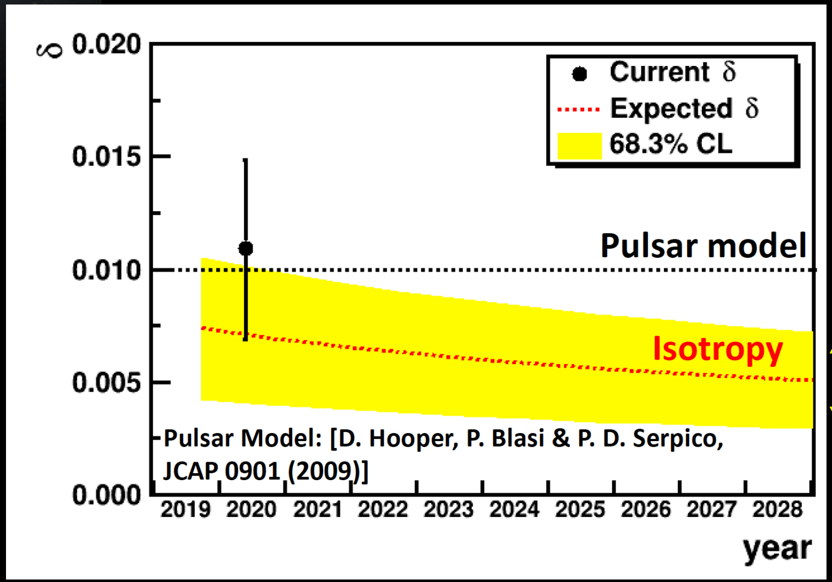



Measurement of the cosmic ray fluxes as function of the arrival direction in **Galactic Coordinates**

**Results consistent with isotropy**

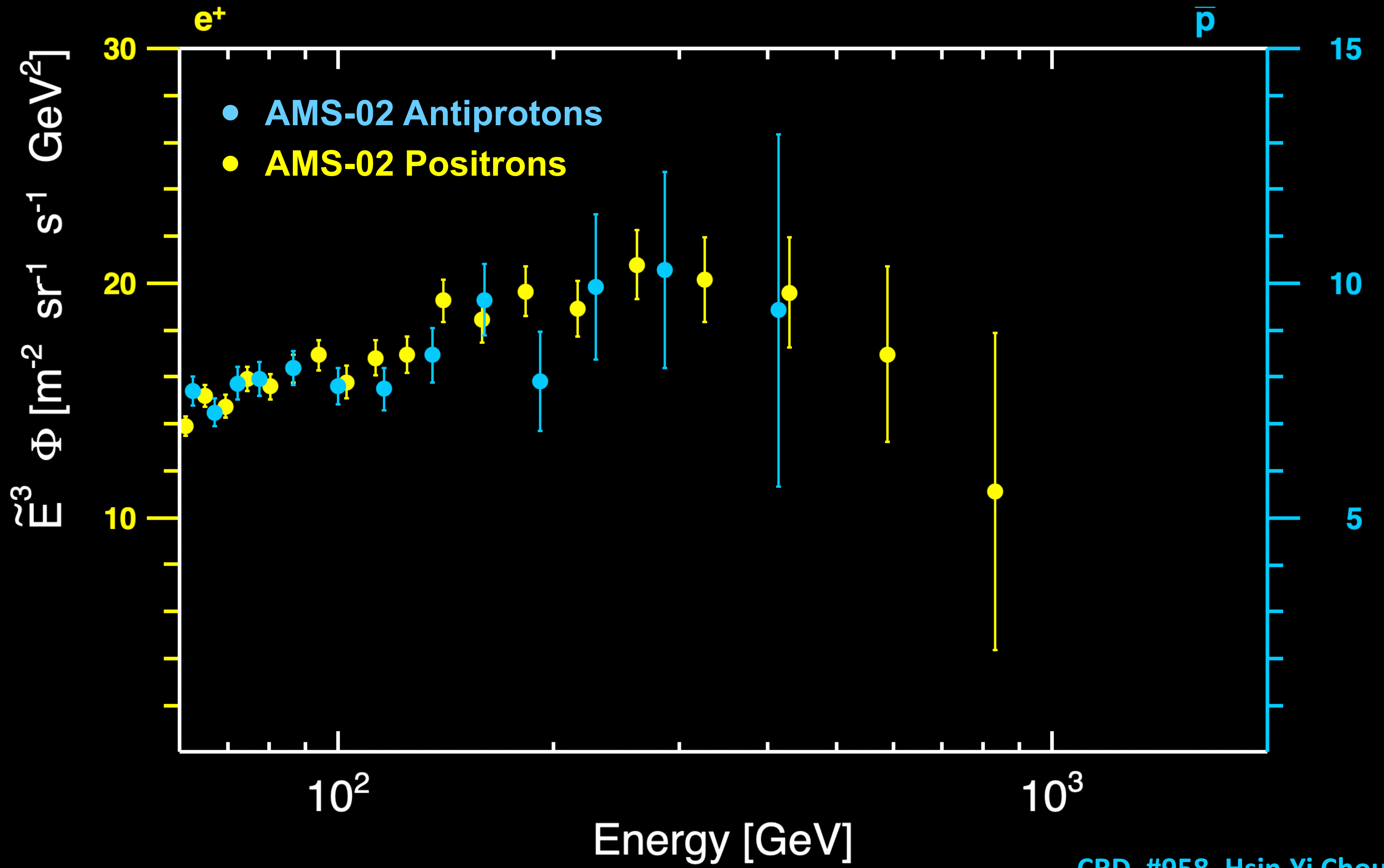
**Amplitude of the dipole anisotropy on $e^+$ for $16 < E < 500$ GeV**
**$\delta < 1.65\%$ at the 95% C.L.**

CRD, #995, Miguel Molero




0.005±0.002

# Positron and Antiproton have nearly identical rigidity dependence.

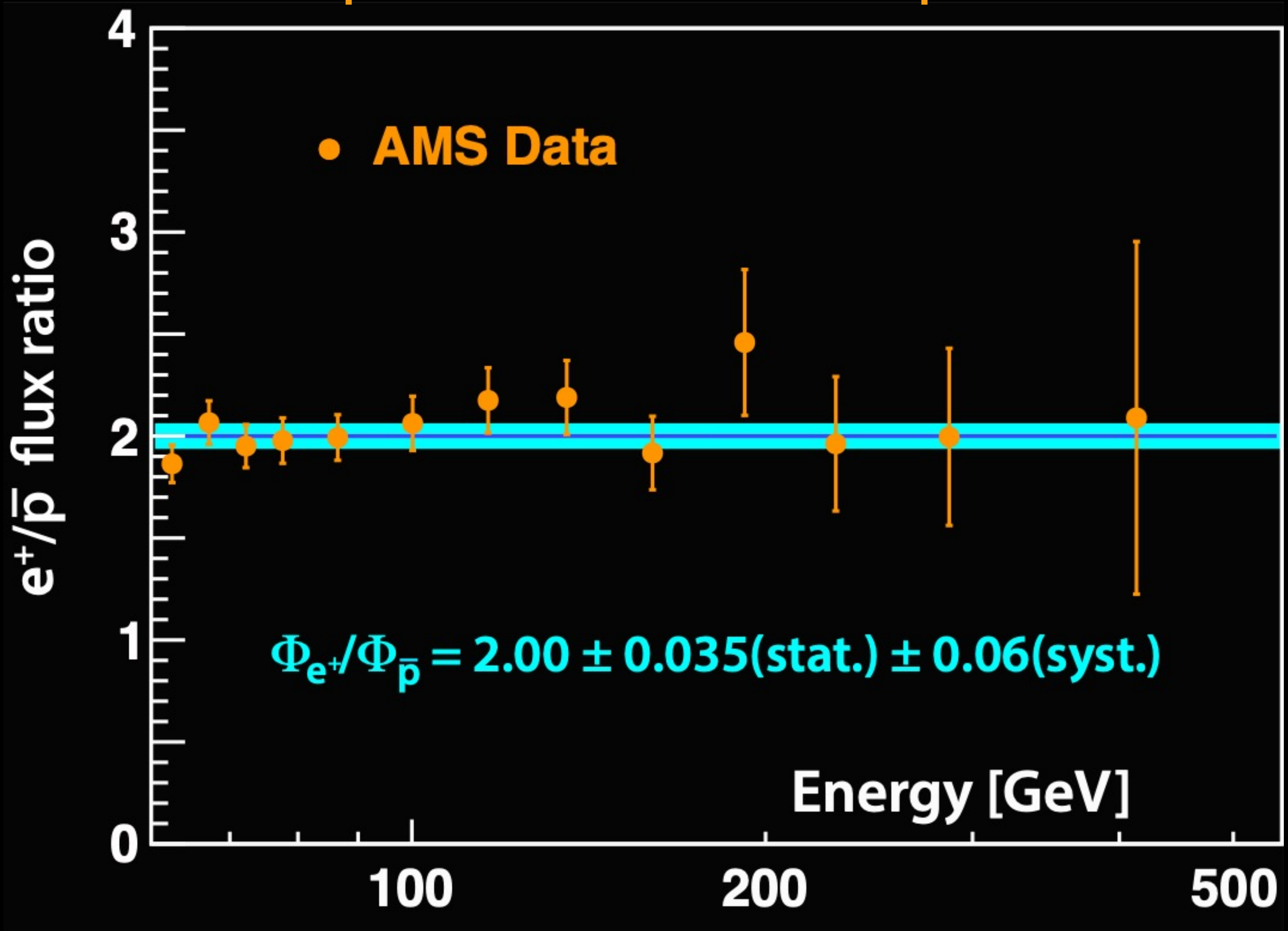



CRD, #958, Hsin-Yi Chou

# Positron-to-Antiproton ratio

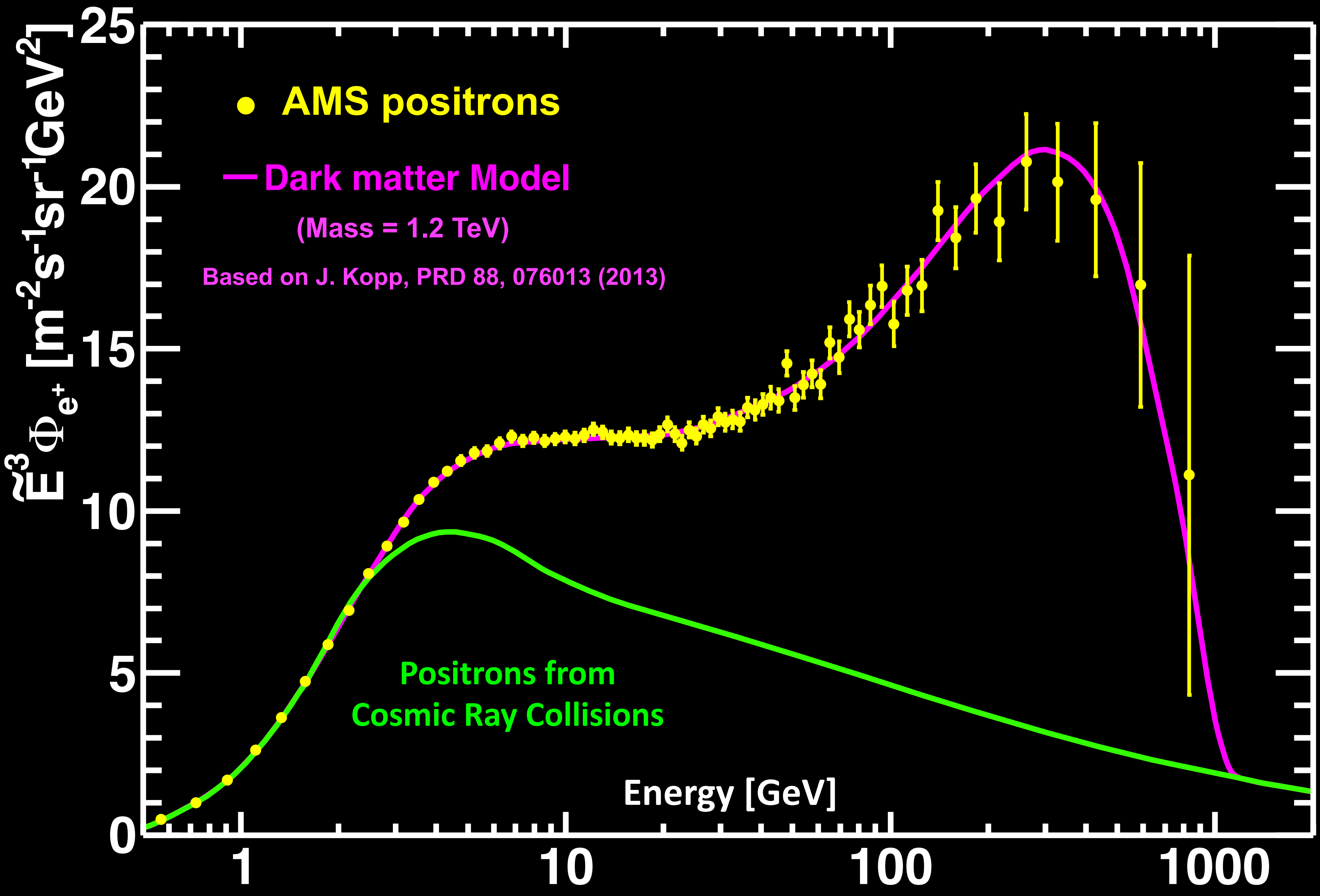
The positron-to-antiproton flux ratio is independent of energy.

Antiprotons cannot come from pulsars.

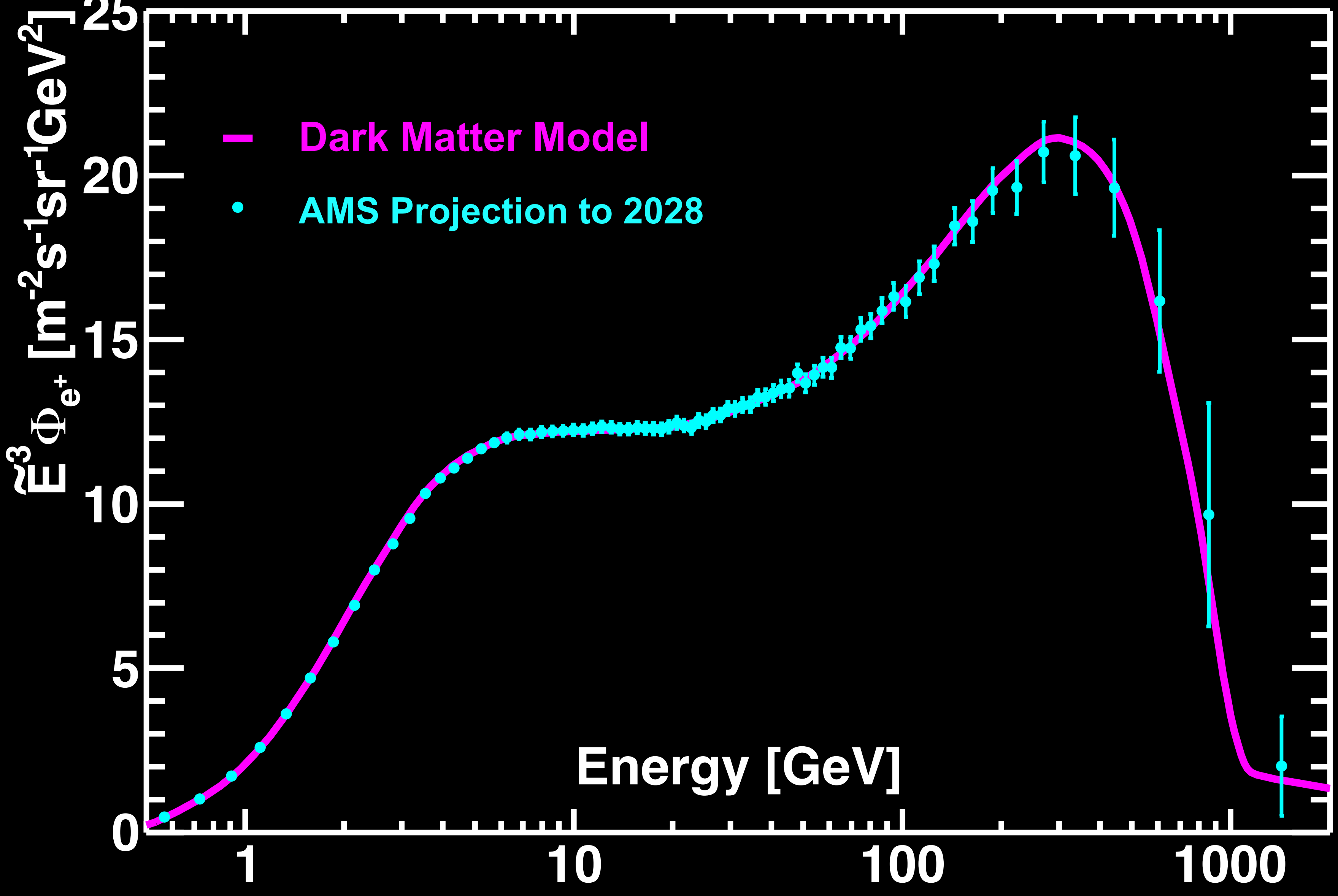


# The Origin of Positrons at high energies

## Particle origin: Dark Matter



# Positrons and Dark Matter Model by 2028



# Conclusion and Outlooks

- **Precision measurements by AMS of the positron flux to 1 TeV.**

- **The positron flux shows distinctive energy dependence:**
  **(a) a significant excess starting from 25.2±1.8 GeV**
  **(b) a sharp drop-off above 284 GeV,**

- **The positron flux is well described by the sum of a diffuse term and a new source term with a finite energy cutoff at 810 GeV, with a significance of more than 4σ.**

- **These properties are not explained by traditional CR models:**
  **An primary source of high energy positrons.**

- **By continuing the measurement through the live time of the Space Station, we will be able to improve the accuracy and extend to higher energy, and determine the origin of high energy positrons.**